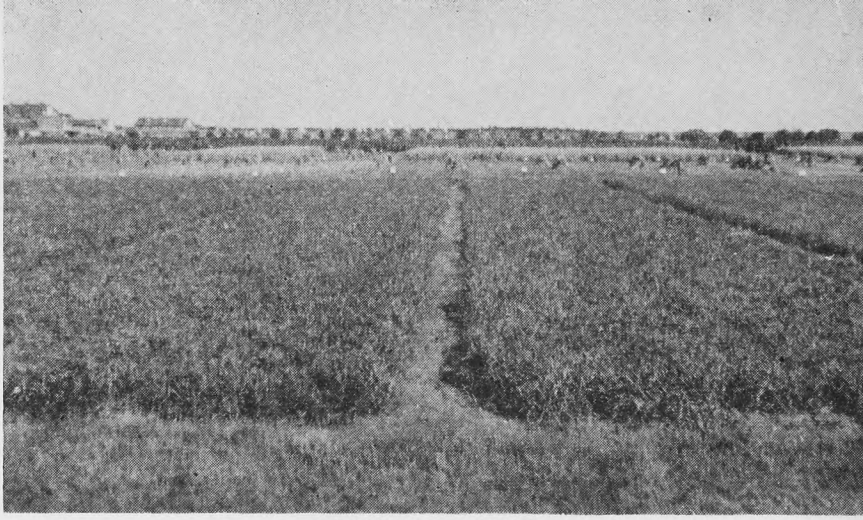

☆ Alfalfa in the Rotation.

a Quarter Century of Crop Rotation Experiments

AGRICULTURAL EXTENSION
Bulletin No. 129

College of Agriculture

University of Saskatchewan
Saskatoon

Contributed by Department of Field Husbandry

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FOREWORD

In this bulletin there is presented the results of more than a quarter century of study of the important problems of crop rotations for Saskatchewan. Complex or longtime rotations have not been widely adopted by farmers in this province. However, serious problems in soil conservation have developed in some areas and it may be that these, combined with a changing price structure, will yet make the use of such rotations necessary.

Looking far ahead, Professor Champlin established the experiments on which this bulletin is based, shortly after he took charge of the Field Husbandry Department thirty years ago. One of his last major activities before he went on retirement leave last October, was to prepare this report for publication. Thus the rotation problem was uppermost in his mind at the beginning and end of his active career on the University staff. He never lost interest in it but carried on patiently with it throughout the period of his administration. To use his slogan, he did it "for the Land's Sake," and the Extension Department is pleased to be able to make it available—for the sake of the land—and its owners.

V. E. GRAHAM,

Dean of Agriculture

A Quarter Century of Crop Rotation Experiments

by MANLEY J. CHAMPLIN (1)

INTRODUCTION

CROP rotation was practised by the ancient Romans more than twenty centuries ago. They understood the value of legumes and the use of the fallow and inter-tilled crops. Various forms of crop rotation have been used in Britain and western Europe for hundreds of years and modified methods of crop sequence have been followed in the United States and eastern Canada for a long time.

Advantages reported have included conservation of moisture by means of fallow and inter-tilled crops, maintenance of humus by the use of perennial grasses and the return of waste products such as stubble, straw and manure to the land and maintenance of nitrogen supplies by the growing of legume crops.

It has also been observed that some insects are less troublesome or are completely controlled by rotation of crops and that some plant diseases are much less injurious when crops that are not closely related occupy the land in different seasons. In addition to all of these, it has been found that erosion of the soil by wind and water, is mitigated by the maintenance of a good supply of fibre or organic matter in the surface soil and perennial grasses are helpful in that connection.

At the time the experiments which will be mentioned in this paper, were begun, the above facts were known and this knowledge was used in planning the research work. Fallow or inter-tilled crops, or both, were used in the various rotations in order to kill weeds and conserve moisture. Organic matter was restored by the conservation of stubble and by the addition of manure at a rate equivalent to one ton per acre, per year, in most of the rotations. This amount was arbitrarily decided upon as an approximation of the amount of waste organic matter that would be produced on the land. For example, livestock farms would produce manure and grain farms would have surplus straw. It was considered best to use a definite amount in order to simplify the interpretation of results. One rotation and one series of continuously cropped plots were left without manure in order to observe the effect upon the soil and the crops.

(1) Senior Professor and Head of the Department of Field Husbandry.

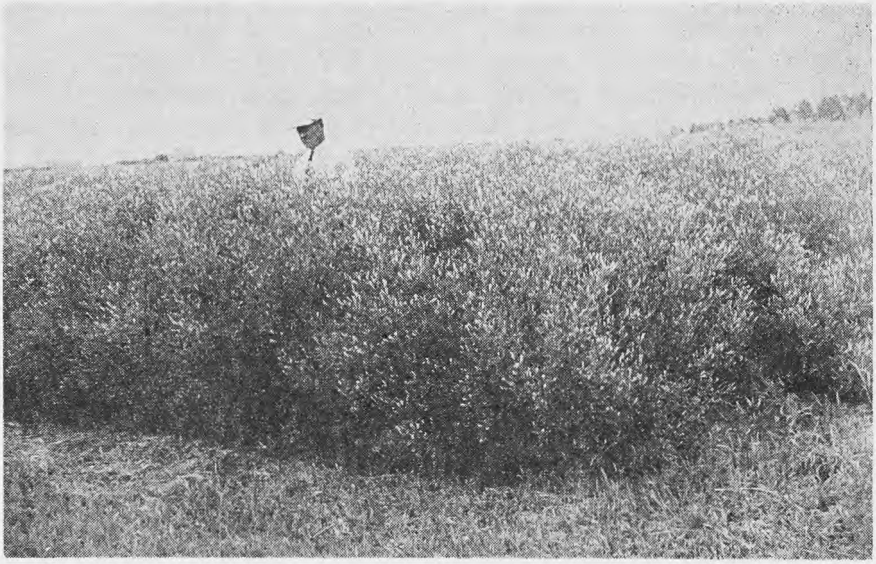

Figure 1.—Sweet Clover, a Soil Building Biennial Legume.

Legumes were introduced into four rotations. These consisted of alfalfa and sweet clover in two each. Grasses, including brome and slender wheat grass were used comparatively in a six field rotation. In addition to the rotations, the important grain crops and corn have been grown continuously.

FLEXIBILITY IS DESIRABLE

Crop rotation is usually defined as the growing of crops in a definitely planned succession, but in many cases, it is very difficult to follow a certain sequence, for various reasons. On that account, it seems very desirable to modify the definition by leaving out the idea of a regular sequence of crops and thus give flexibility to the rotation.

For example, perennial grasses or alfalfa or a mixture of grass and alfalfa can be grown for several years on one field while other fields are devoted to annual crops and fallow. If annual charts are kept showing the crops grown on different fields it is possible to plan so that the perennials are eventually grown on each part of the farm. This gives much of the benefit to be derived from rotation of crops without the inconvenience of trying to follow a definitely planned sequence. In our experiments, definitely planned sequences were followed in order to be able to compare the results obtained from different ones.

PLAN OF THE EXPERIMENTS

The experiments were planned with a view to comparing the yields of the various crops grown continuously with the yields of similar crops when grown in one or more of six different rotations and also to compare the value per acre of the produce grown in each of the rotations.

In addition to yields of crops and values per acre obtained from the different sequences, considerable other information was obtained including the protein content of wheat and the prevalence of weeds in the different systems of cropping. A total of 382 experimental plots were used, occupying about 28 acres of land on the Field Husbandry Experiment Station of the College of Agriculture of the University of Saskatchewan at Saskatoon. The soil has been classified as Elstow silty loam and the long time average rainfall is just under 14 inches per year. The soil is naturally fertile and the low precipitation makes the moisture factor a very important one.

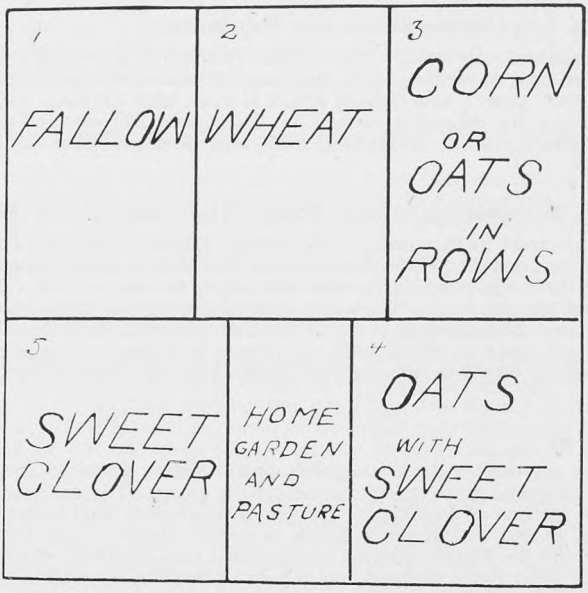

Figure 2.—Rotation A, with Five Fields Each Year. Weed Control, Humus and Nitrogen Conservation Are Provided.

The letters in the word *rotations* have been used to designate the different systems which are explained in the following paragraphs.

R.—Continuous Cropping.

Barley, corn, emmer, flax, oats, rye and wheat are grown each year on the same land. Weeds are kept under control by any means available, the object being to determine actual production of crops growing continuously with as little interference from weed growth as possible.

These plots are grown in triplicate series. Two series are manured at intervals of six years, the third being left without manure. The rate used is six tons per acre, which amounts to one ton per acre, per year.

O.—Alternate Cropping.

The chief cereal crops, wheat, oats and barley are grown in duplicate series and one plot of spring rye is sown on each of three different moisture conservation methods; fallow, corn in hills 42 inches apart and oats in double rows 36 inches apart. All of the land receives manure at the rate of six tons per acre, once in six years, or at the rate of one ton per acre per year, the manure being applied previous to fallow or row crops.

T.—Three Fields, Introducing Sweet Clover.

This is the same as Rotation O except that sweet clover is sown with the cereal crops and three fields are used instead of two. Thus, moisture is conserved only once in three years, instead of every second year. The land is manured at the rate of six tons per acre once in six years, the manure being applied previous to fallow or row crops.

A.—Five Fields Introducing Two Methods of Moisture Conservation and Sweet Clover.

This rotation includes fallow, wheat, corn, oats and sweet clover. Thus, the wheat is sown on fallow, the oats with sweet clover on corn ground; the sweet clover is cut once or twice for hay depending upon the seasonal conditions and the stubble is plowed for fallow early in June of the following year.

I.—Four Fields, Introducing Alfalfa as a Supplement.

Fallow, wheat and oats occupy three fields. The fourth is in alfalfa which remains for six years from time of seeding, while the crops on the other three fields rotate twice around. Every sixth year, a new field of alfalfa is sown with the oats, and the old field is plowed for fallow the following June. Thus, it requires 20 years for the rotation to complete one entire cycle, so that alfalfa will have been produced for five years on each of the fields.

N.—Six Fields, Introducing Alfalfa, Brome Grass and Slender Wheat Grass.

Six fields are used in this rotation as follows: fallow, grain, oats in rows, wheat seeded in separate plots to alfalfa, brome grass and slender wheat grass. The alfalfa and grasses are cut for hay during the two years after seeding and are then plowed for fallow in June of the third year. Manure is applied during the fallow year, at the rate of six tons per acre, amounting to one ton per acre, per year. This experiment enables us to compare the effect of alfalfa with the effects of brome, a creeping rooted grass and slender wheat, a bunch or non-creeping grass, upon the yields of subsequent cereal crops.

S.—Three Fields.

Three fields are used and are rotated in order: fallow, wheat, oats. No manure is applied and no perennial grass or leguminous crop is grown. It is designed to represent a very common method of farming in this province, wherein summerfallow is followed by two crops of grain. No attempt is made to restore humus except that the stubble is conserved. It will be of great interest to determine how long this relatively new, rich soil will produce good crops without any return of fertility. Changing from fallow to wheat to oats provides well for the control of insects and diseases that are destructive to one crop only, as it gives them no opportunity to accumulate in the soil.

COMPARISON OF AVERAGE VALUES PER ACRE, OBTAINED FROM VARIOUS ROTATIONS

Since it is obviously impossible to compare one complete rotation with another without some common denominator, we have made use of the average farm values, as supplied by the Dominion Bureau of Statistics, for the various crops grown. These have been set forth in Table 1 for the years 1925 to 1949 inclusive.

TABLE 1

Average Farm Prices for Saskatchewan from the Dominion Bureau of Statistics, 1925-1949, inclusive. The Data for 1925-1930 were taken from the Quarterly Bulletin of Agricultural Statistics for January, 1931; 1931-1932 from the same for January, 1933; 1933-1939 from the same for January, 1940; 1940-1943 from the wartime issue for October, 1942, March, 1944; 1944 from the bulletin for December, 1944; 1945-1947 from the same for January, 1948; 1948 from the same for October, 1948; 1949 from the same for February, 1950. Grain prices are per bushel and Hay or Fodder prices are per ton.

Year	Wheat	Oats	Barley	Rye	Flax	Brome Grass	Slender Wheat Grass	Sweet Clover	Alfalfa	Corn Fodder
1925	$1.25	$0.35	$0.47	$0.72	$1.84	$10.45	$10.45	$10.45	$14.44	$ 8.93
1926	1.08	0.42	0.45	0.74	1.60	8.00	8.00	8.00	13.25	10.00
1927	0.97	0.44	0.61	0.79	1.52	8.76	8.76	8.76	12.96	8.00
1928	0.77	0.38	0.48	0.74	1.56	7.96	7.96	7.96	12.80	5.30
1929	1.03	0.50	0.51	0.82	2.37	11.48	11.48	11.48	13.44	10.22
1930	0.47	0.15	0.12	0.17	0.89	8.25	8.25	8.25	12.00	7.00
1931	0.38	0.18	0.21	0.23	0.77	7.10	7.10	7.10	9.00	4.70
1932	0.35	0.13	0.19	0.24	0.60	5.50	5.50	5.50	8.50	4.00
1933	0.47	0.19	0.24	0.31	1.19	4.50	4.50	4.50	7.18	4.67
1934	0.61	0.27	0.47	0.46	1.13	5.67	5.67	5.67	7.70	6.41
1935	0.60	0.17	0.24	0.25	1.18	4.89	4.89	4.89	7.83	5.67
1936	0.92	0.35	0.67	0.63	1.44	5.35	5.35	5.35	9.23	5.40
1937	1.05	0.38	0.46	0.67	1.42	7.50	7.50	7.50	9.50	6.50
1938	0.58	0.16	0.22	0.25	1.11	5.75	5.75	5.75	8.50	5.60
1939	0.51	0.20	0.26	0.35	1.38	5.30	5.30	5.30	7.50	5.50
1940	0.53	0.21	0.27	0.30	1.05	5.75	5.75	5.75	7.94	5.00
1941	0.53	0.34	0.40	0.41	1.25	6.00	6.00	6.00	8.45	5.30
1942	0.69	0.35	0.44	0.45	2.00	5.80	5.80	5.80	7.60	7.30
1943	1.02	0.48	0.60	0.82	2.20	6.50	6.50	6.50	8.75	6.40
1944	1.05	0.50	0.64	0.85	2.42	7.00	7.00	7.00	10.00	5.50
1945	1.16	0.50	0.65	1.63	2.51	9.23	9.23	9.23	12.38	6.00
1946	1.14	0.52	0.69	2.27	2.99	10.42	10.42	10.42	13.93	8.00
1947	1.15	0.61	0.84	3.24	5.22	13.41	13.41	13.41	16.72	10.00
1948	1.35	0.62	0.92	1.38	3.86	13.75	13.75	13.75	17.25	13.86
1949	1.53	0.52	0.78	1.22	3.32	13.44	13.44	13.44	17.35	13.75

These values represent an estimate of the average prices received for farm products by Saskatchewan farmers.

A COMPARISON OF THE VARIOUS ROTATIONS

The values per acre, as presented in Table 2, have been calculated by multiplying the yields per acre of the various crops each year by the farm values given in Table 1, then reduced by the proportion of the land in fallow, if any, and finally averaged for the 25 years, 1925 to 1949 inclusive. No values have been assigned for the straw produced by the grain crops although it would be worth considerable upon diversified farms producing livestock and of course, the best market for the hay and fodder crops in some of the rotations would be obtained by feeding them on the farm where they are produced. Thus, the values given would tend to be conservative.

It seems logical to assume that if rotations or farming systems that provide for conserving soil moisture, controlling weeds by economical methods, maintaining soil humus, helping to prevent soil drifting and providing feed for the farm livestock will give returns that are at least equal to those obtained from farm systems that do not return anything to the soil, such soil conserving rotations should be more desirable than the ones which merely mine the soil of its plant food.

The results of the first 25 years of this investigation give evidence that it will be possible to gradually replace the pioneer system of land exploitation with methods that promise more permanence. Even though much of the better land is not showing serious signs of depletion as yet, it is not too early to begin to develop more permanent methods, because the changes cannot be made in a year or even in a decade. They must be made cautiously and slowly, with care to make adjustments suitable to local conditions.

TABLE 2

Average Annual Values per acre produced by various farming systems at Saskatoon during the years 1925 to 1949. In three Rotations, O, T and N, the Barley, Oats, Rye and Wheat were grown separately on the Fallow in each Sequence, except that in Rotation N, one kind of grain was grown each year from 1945 to 1949, inclusive.

Rotation	Sequence of Crops	Average
O-1	Fallow, grains	$12.15
O-2	Corn, grains	13.37
O-3	Oats in rows, grains	14.67
T-1*	Fallow, grains, sweet clover	11.30
T-2*	Corn, grains, sweet clover	12.02
T-3*	Oats in rows, grains, sweet clover	13.04
N-1**	Alfalfa, alfalfa, fallow, grains, oats in rows, wheat	12.02
N-2**	Brome, brome, fallow, grains, oats in rows, wheat	10.74
N-3**	Slender wheat, slender wheat, fallow, grains, oats in rows, wheat	11.58
A	Fallow, wheat, corn, oats, sweet clover	13.33
I	Fallow, wheat, oats, alfalfa (six years)	14.54
S	Fallow, wheat, oats	13.39

*In 1945 and 1948 the sweet clover crop was destroyed by weevils so field peas were substituted for the sweet clover.

**Instead of growing four different grains in this rotation it was simplified in 1945. Flax was grown on the fallow in 1945-1946 and barley in 1947-1948.

In two rotations, O and T, the grain crops, wheat, oats, barley and spring rye were grown separately on land which was used for three different methods of moisture conservation the previous year, including fallow, corn in hills 42 inches apart and double rows of oats 36 inches apart. Table 3 gives the average values per acre produced by each of these crops. A study of this table indicates that wheat has usually been the most valuable cash crop at Saskatoon. The differences are not large, however, indicating that where feed grains are needed or where some local condition warrants the production of the other grain crops it would be all right to grow them. For example, rye does better than wheat on light or sandy land, barley competes with weeds better than wheat and oats are not subject to some of the insect pests or diseases that attack wheat.

Rotation N was designed for the purpose of introducing perennial grasses and alfalfa into a systematic rotation of crops, occupying six fields including fallow, grain, oats in double rows 36 inches apart and wheat sown to grass or alfalfa which was left

Figure 3.—Oats in Double Rows, 36 Inches Apart.

Figure 4.—Slender Wheat Grass in Rotation N.

to produce crops for two years. In order to compare the results obtained by using brome, a creeping rooted grass, slender wheat, a non-creeping type of grass and alfalfa, each field was divided into three parts.

For the first 20 years, 1925 to 1944, separate plots of wheat, oats, barley and spring rye were grown on the fallow following each type of grass and the alfalfa. In 1945, it was decided to simplify the experiment by growing one kind of grain crop on all of the fallow. Accordingly, flax was sown in 1945 and 1946. It was found, however, that two years in hay crops did not give sufficient weed control, even after fallowing, to provide proper conditions for flax production and it was decided to use barley as the grain crop on the fallow from 1947 to 1949. This has proved to be a satisfactory change and has resulted in better weed control.

The average values per acre produced by each of the three parts of Rotation N are presented in Table 2. It will be observed that the rotation N_1, with alfalfa ranked first in acre value, while N_3 with slender wheat grass was second and N_2 with brome grass was third. This experiment indicates that slender wheat grass is better as a short-lived perennial in a rotation than brome grass. It also showed that alfalfa produced more value per acre, under the conditions prevailing, than either of the grasses. A further conclusion was that brome grass and alfalfa are not very suitable for systematic rotations, in which they must be plowed the third year after sowing. Such crops can be used to better advantage as supplements to the regular rotation, so that they can be left in the same field for at least five years as illustrated by Rotation I.

TABLE 3

A comparison of the Average Values per Acre obtained from Rotations O and T; Wheat, Oats, Barley and Spring Rye having been grown in each Rotation each year from 1925 to 1949 and the values computed separately.

Rotation	Sequence of Crops	Wheat	Oats	Barley	Rye
O-1	Fallow, grains	$14.27	$11.82	$12.35	$13.57
O-2	Corn, grains	13.54	13.44	13.61	13.07
O-3	Oats in rows, grains	15.22	13.63	14.86	15.28
T-1*	Fallow, grains, sweet clover	12.66	12.03	11.11	11.89
T-2*	Corn, grains, sweet clover	12.53	11.86	11.21	12.16
T-3*	Oats in rows, grains, sweet clover	13.18	12.14	12.70	13.89

*In 1945 and 1948 the sweet clover was destroyed by weevils and field peas were substituted for the clover.

Rotation A, fallow, wheat, corn, oats and sweet clover, has proved to be a more satisfactory method of introducing sweet clover into a rotation than has the three-year Rotation T. In this rotation, moisture conservation and weed control are provided by the cultivation of the fallow and the corn field. Sweet clover, sown with oats on clean corn stubble land has given satisfactory stands. One fifth of the land in sweet clover has been sufficient to provide a considerable amount of hay and to improve the soil texture. The same proportion of the land in corn for fodder may provide more fodder than is needed. In that case, a part of the field may be fallowed or sown to grain in double rows.

It will be understood that such a rotation is suitable only to a farm where cattle are kept but it could be modified for mechanized farming by plowing the sweet clover when six to twelve inches high for fallow and substituting fallow for corn, thus providing for moisture conservation and the beneficial effects of the clover roots. The rotation would thus require four fields: fallow, wheat, fallow or oats in rows, oats or wheat seeded to sweet clover.

In Rotation I we have tried a method of supplementing the common Saskatchewan rotation of fallow, wheat and oats with alfalfa. The rotation is practical and adaptable and it provides for moisture, humus and nitrogen conservation, weed control and two cash grain crops. In addition to these advantages, it has given us an average return per acre of $14.54 for 25 years, which compares favorably with other types of rotation as set forth in Table 2.

A farm operated according to this system, would be divided into four fields as follows:

Alfalfa sown with oats to remain for six years from time of seeding; (1) fallow; (2) wheat; (3) oats. The crops on fields 1, 2 and 3 are rotated twice around. Alfalfa is sown with oats in the second round. When the new alfalfa field is thus established, the old field is plowed up and fallowed, thus becoming the fallow in the three field rotation, fallow, wheat, oats. The same process is repeated every sixth year. This gives the alfalfa a chance to produce hay crops for five years before it is plowed up. Experience has shown that the alfalfa remained in good condition during the five year period and we have been fortunate in securing a stand each year but one, when the alfalfa was seeded. To remedy that condition, we reseeded the alfalfa in the oat stubble the following spring and secured a good stand.

In practical farming, this rotation can be made very elastic by leaving the alfalfa any number of years desired or as long as it is producing well, meanwhile, rotating the other three fields with fallow, wheat and oats and applying any manure available to the land to be fallowed.

Rotation S: This rotation consists of fallow, wheat and oats. The fallow field gives an opportunity to kill weeds and conserve moisture. Changing from wheat to oats is a sanitary measure, in that some of the plant diseases and insect pests that infect wheat do not attack oats and some that injure oats do not damage the wheat. As shown in Table 2, the average value per acre of crops produced has amounted to $13.33 as compared to $14.54 for Rotation I, which is similar, except that alfalfa is grown on a fourth field as explained above. The soil has shown some deterioration in texture.

When this rotation is used in regular farm practice, it would be desirable to conserve as much of the straw, stubble or barnyard manure as possible. The stubble could be worked into the land and manure or old straw could be applied to the fallow field.

A DISCUSSION OF CONTINUOUS CROPPING

This is the opposite of crop rotation but it is a necessary part of an experimental project of this kind because it gives a comparison each year with similar crops, grown in rotations. In addition, many interesting developments have been noted. Weed control and lack of moisture conservation have been the most serious problems to date, except for the corn crop. Failures of wheat and other grain crops, due to drought, resulted in 1933 and 1937 and yields were low in 1931, 1936, 1941, 1945, and 1947. The evidence has shown that continuous cropping is very hazardous, so far as individual years are concerned, although the average values per acre for the 25 year period, as shown in Table 5, have held up fairly well. The risk of crop failures or near failures, of the crops other than corn under continuous cropping, has been greater than in rotations where moisture conservation has been provided.

In order to start the experiment the land was summerfallowd in 1922. Three plots of each crop; barley, corn, emmer, flax, oats, rye and wheat, arranged in triplicate series, were sown in 1923 and have been continuously sown each year since. The average values for all crops as reported in Table 4, except for flax, began with the 1925 crop so that the values shown would not be influenced by the fallow in 1922. The average values for flax include the years 1929 to 1948.

VALUE OF MANURE

Two plots of each crop were manured at the rate of six tons per acre every sixth year, equivalent to one ton per acre, per year. The values reported in Table 4 for manured plots are computed from the average yields of the two plots. In order to obtain some idea of the value of manure in terms of increased crop yields, one plot of each crop was not manured. All crops were increased by the manure.

Limitations of land available for this experiment influenced us in using only one unmanured check plot instead of duplicating it as was done with the manured plots, but considering the uniform character of the land used we feel sure that the differences shown give a very fair idea of the value of the manure in terms of increased crop production.

The occasional dry year resulted in a crop failure which did not occur on fallow or cultivated land. Insect pests and plant diseases have caused less damage to the crops in this experiment than was expected and probably less than would be experienced in many cases if this method of cropping were adopted on a large scale. Costs of seeding and harvesting are increased when all the acreage is sown to grain instead of having part of the land in fallow, grasses and cultivated crops as would be the case under crop rotation.

For the above reasons, we do not recommend continuous cropping to grain except under conditions where soil drifting is serious enough to prevent fallowing and where shortage of labour, water for livestock or some other circumstances prevents the use of a diversified system of farming.

TABLE 4

Average annual values per acre of various crops grown continuously during the years 1925 to 1949, manured at the rate of six tons per acre every six years, compared with no manuring. Emmer was valued at the same price as Barley.

	Barley	Corn	Emmer	Flax*	Oats	Rye	Wheat
Manured	$13.85	$8.68	$10.13	$13.35	$13.26	$13.42	$13.90
Not manured	12.04	7.36	8.59	11.42	12.14	11.16	13.51
Gain from manure	1.81	1.32	1.54	1.93	1.12	2.26	.39
Returns per ton of manure	1.81	1.32	1.54	1.93	1.12	2.26	.39

*Averages for 1929 to 1948 inclusive are not directly comparable to other crop values. Due to excessive weed growth in the flax plots in 1949 that year was not included in the flax averages.

If it is necessary to engage in continuous cropping to grain, it is suggested that two crops of wheat or barley be followed by an early variety of oats, which would make it possible to kill a growth of weeds before seeding the oats. The use of clean seed grain and every other possible precaution is also required for the control of weeds in order to have reasonable success with this method of farming.

FLAX UNDER CONTINUOUS CROPPING

When the experiment was started in 1923, Crown flax was the leading variety in Saskatchewan. This variety is susceptible to wilt but is fairly resistant to rust. When grown on land that was new or had not had flax before, it has produced good yields. To find out more about the effect of wilt disease upon flax in this climate, Crown was sown each year from 1923 to 1928, inclusive. A satisfactory crop was produced the first year but in 1924, enough wilt disease had developed to destroy about half of the plants.

From 1925 to 1928, the yields were negligible but each year a few plants survived the disease. Following the method used so successfully at the North Dakota Agricultural College, selections were made from among the surviving plants with a view to developing a wilt resistant variety. One of the wilt-sick plots was used as flax nursery until 1939. As a result of this work, Royal, a wilt and rust resistant variety, has been developed and distributed to the farmers of Saskatchewan.

From 1929 to 1949, wilt resistant varieties of flax have been sown each year. From these experiences, it is quite clear that wilt disease is very destructive in this climate and it is necessary to sow wilt resistant varieties, except on land that is new to flax.

CORN AS A CONTINUOUS CROP

Corn as a continuous fodder crop has not shown any injury from disease or insect pests. Continuous cultivation has kept the land practically clear of weeds. The manured land has yielded more fodder than the unmanured land. Yields have not been large but the quality of the fodder has been good. It is quite probable that greater returns per acre could be realized than the values shown in Table 4 if the fodder could be fed on the farm. In rotations, the corn crop has a special value, in that the clean cultivation which it receives kills weeds and prepares the land for a grain crop the following year.

PROTEIN CONTENT OF WHEAT

Through the courtesy of the Department of Chemistry, we have been able to assemble considerable data regarding the protein content of wheat, grown in the various rotations and as a continuous crop, with and without manure. These data are presented in Table 5.

The climatic conditions at Saskatoon are generally favourable to the development of a high percentage of protein in wheat, due to the quick ripening of the crop almost every season. The lowest average for the 25 year period was 14.3 per cent. This was obtained by growing wheat continuously without manuring. Continuously grown wheat with manure applied, averaged 15.2 per cent. The highest average protein content, 15.9 per cent was obtained in Rotation N_1, a six year rotation, including two years in alfalfa. Wheat grown in all of the rotations except O_3, gave an average percentage of protein of 15 or more.

The variations in the average protein content of wheat grown in the different rotations was small. This is probably due to the fact that the wheat crop in all the rotations was grown either on fallow or on cultivated row crop land. The soil is naturally fertile and the cultivation apparently made sufficient nitrates available to provide for the normal development of protein.

Variations in the five year averages are also shown in Table 6. Seasonal conditions produced greater variations than did the crop sequences. The data for single seasons support the belief that there is a definite relationship between the length of the maturing period and the protein content of wheat. Warm, dry weather, after the wheat headed out, hastened maturity and increased the percentage of protein.

TABLE 5

Effect of various Rotations upon the Percent of Protein in Wheat*

Name of Rotation	Sequence of Crops	1925-1929	1930-1934	1935-1939	1940-1944	1945-1949	1925-1949
R_1	Continuous cropping, manured	13.0	15.6	16.2	15.3	15.9	15.2
R_2	Continuous cropping, no manure	11.7	14.7	16.2	13.7	15.4	14.3
O_1	Fallow, wheat	13.8	15.0	16.5	15.2	16.1	15.3
O_2	Corn, wheat	13.4	15.3	16.3	14.8	15.4	15.0
O_3	Oats in rows, wheat	12.2	14.9	16.3	14.0	14.9	14.5
T_1	Fallow, wheat, sweet clover	14.2	15.5	17.2	15.4	16.4	15.7
T_2	Corn, wheat, sweet clover	14.2	15.7	16.9	15.3	16.2	15.7
T_3	Oats in rows, wheat, sweet clover	13.4	16.4	16.9	15.5	16.8	15.8
N_1	Fallow, grains, oats in rows, wheat alfalfa, alfalfa	13.6	16.4	16.9	15.6	17.2	15.9
N_2	Fallow, grains, oats in rows, wheat brome grass, brome grass	13.2	16.0	16.4	14.5	16.7	15.4
N_3	Fallow, grains, oats in rows, wheat slender wheat, slender wheat	13.4	15.9	16.3	14.7	16.5	15.4
A	Fallow, wheat, corn, oats, sweet clover	14.4	15.6	——	——	15.9	15.3
I	Fallow, wheat, oats, alfalfa	13.4	15.9	——	——	15.9	15.0
S	Fallow, wheat, oats	14.3	16.1	16.7	14.8	16.4	15.7

*In 1925 there were no data for R_2; nor for Rotation A, I and S in 1933 nor for rotations A and I from 1935 to 1944. In 1937 and 1941, the crop failed on R and in 1940 no protein data were recorded. The loss of records was due to changes in staff and the necessary training of new workers.

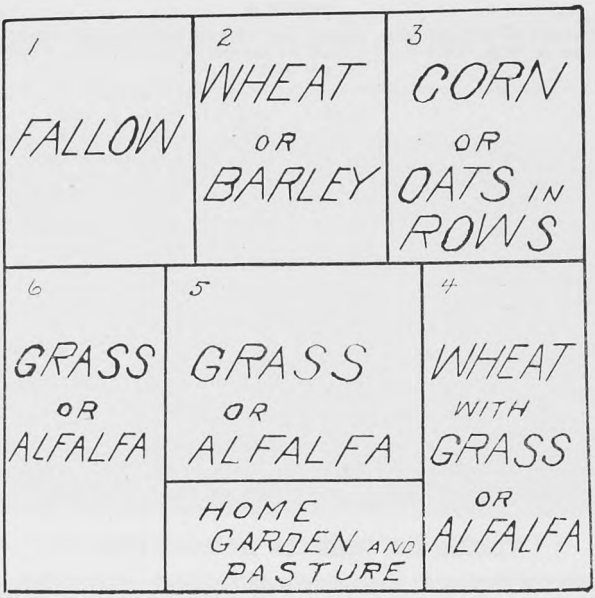

Figure 5.—Rotation N, in which Alfalfa or Grasses were used as Triennials.

SIZE OF KERNELS OF VARIOUS GRAIN CROPS GROWN CONTINUOUSLY AND IN DIFFERENT ROTATIONS

A study was made of the size of kernels of wheat, oats, barley and spring rye as well as of oats grown in cultivated, double rows 36 inches apart as indicated by the weight of 1,000 kernels in grams.

Wheat and rye kernels were larger, when grown on clean, cultivated fallow or corn ground than when grown as continuous crops, thus responding to the better supply of soil moisture, following clean cultivation the previous year.

No important differences were found in the weights per 1,000 kernels of oats and barley grown in the various sequences but oats grown in cultivated rows were heavier, as an average, than those grown in the usual way. This again emphasized the importance of soil moisture in this region. The oats grown in rows had a larger area in which to develop and the clean cultivation between the rows prevented much competition from weeds.

YIELDS OF CEREALS IN THE TWO YEAR ROTATION O

In Table 6, the yields in bushels per acre, that were obtained in Rotation O are reported. Three different methods of moisture conservation were used; fallow, corn in hills 42 inches apart and oats in rows 36 inches apart. The four cereal crops, wheat, oats, barley, and spring rye were grown on each of these preparations.

A study of the data indicates that yields of all the cereals were best on fallow, second best after corn and lowest after oats in rows. This shows that summer fallowing was the most effective of the three methods of moisture conservation under central Saskatchewan conditions. However, when the value of the crop of oats grown in rows is added to the value of the cereal crops, the return, per acre of land used, is highest of the three methods as shown in Table 2. The rotation of corn and cereals gave acre values intermediate between the other two.

Fallow, as a preparation for cereals, has the advantage of convenience but may lead to soil drifting. The decision, as to whether to use row crops in rotation with cereals instead of fallow, rests largely upon whether abundance of land is available or not and whether liability to soil drifting is a serious factor. If it is desired to keep a large proportion of the land in crop, either corn or oats in double rows can be grown.

TABLE 6

Comparison of yields of Wheat, Oats, Barley and Rye under alternate cropping; O_1, Fallow, Cereals; O_2, Corn in Hills, Cereals; O_3, Oats in Double Rows, Cereals. Yields are in bushels per Acre.

Crop	1925-1929	1930-1934	1935-1939	1940-1944	1945-1949	1925-1949
Wheat O_1	38.52	30.62	23.14	37.44	27.32	31.4
Wheat O_2	36.84	18.28	18.60	28.76	13.30	23.2
Wheat O_3	32.50	14.34	17.14	22.72	13.42	20.0
Oats O_1	84.54	61.50	46.94	72.42	52.22	63.7
Oats O_2	87.18	51.14	45.64	63.60	30.54	55.6
Oats O_3	67.98	38.72	36.92	47.02	27.32	43.6
Barley O_1	65.26	54.22	36.32	52.54	41.94	50.1
Barley O_2	65.60	41.82	33.56	48.08	27.00	43.2
Barley O_3	53.04	30.96	27.38	41.56	21.80	34.9
Rye O_1	47.18	28.42	28.84	35.80	27.36	33.5
Rye O_2	44.92	19.16	23.80	32.08	14.16	26.8
Rye O_3	36.86	16.52	17.98	25.78	15.42	22.5

In seasons of abundant moisture the cereals following row crops have more closely rivalled those grown on fallow. A practical compromise solution would be to grow row crops on one fourth of the land, fallow one fourth and raise cereal crops on the remaining half.

YIELDS OF CEREALS IN ROTATION T

This rotation is similar to Rotation O, except that sweet clover has been sown with the grain crops and harvested as a hay crop the following year. The same three methods of moisture conservation have been used; fallow, corn and oats in rows. Thus the rotation requires three fields and the moisture conservation occurs only once in three years. To offset this, the first crop of sweet clover was harvested for hay and the second growth was plowed under early in the fall, so that if any rains occurred in September, moisture would be conserved.

The yields per acre obtained are presented in Table 7. A study of these data shows that the average yields of the various cereals have followed the same pattern as those presented for Rotation O. This method of introducing sweet clover has been useful for experimental purposes but probably involves too high a proportion of the land in sweet clover for a practical farm rotation.

TABLE 7

Comparison of yields of Wheat, Oats, Barley and Rye under a Triennial Rotation. T_1, Fallow, Cereals, Sweet Clover; T_2, Corn, Cereals, Sweet Clover; T_3, Oats in Rows, Cereals Sweet Clover. Yields are in bushels per acre.

Crop	1925-1929	1930-1934	1935-1939	1940-1944	1945-1949	1925-1949
Wheat T_1	37.20	26.12	18.64	36.12	26.54	28.9
Wheat T_2	36.94	17.58	18.28	33.44	14.84	24.2
Wheat T_3	34.76	10.82	14.88	25.08	11.98	19.5
Oats T_1	94.30	69.78	47.98	80.72	54.40	69.4
Oats T_2	84.00	48.54	41.38	70.64	34.72	55.9
Oats T_3	71.54	34.66	35.26	58.00	25.54	45.0
Barley T_1	59.48	58.28	35.76	56.08	42.86	50.7
Barley T_2	56.24	39.42	30.98	48.92	26.38	40.4
Barley T_3	48.94	29.18	26.34	36.42	23.26	32.8
Rye T_1	45.52	26.58	26.28	39.06	28.64	33.2
Rye T_2	43.20	15.72	23.00	36.50	16.92	27.1
Rye T_3	45.20	13.08	18.70	29.24	15.70	24.4

We have learned from it that, wheat, oats and spring rye made better nurse crops than barley. We have also found that it was possible to obtain stands of sweet clover, each year, when sown on all three methods of moisture conservation, although the row crop preparation proved more satisfactory than fallow for seeding sweet clover, in season when high winds in May caused soil drifting on the fallow.

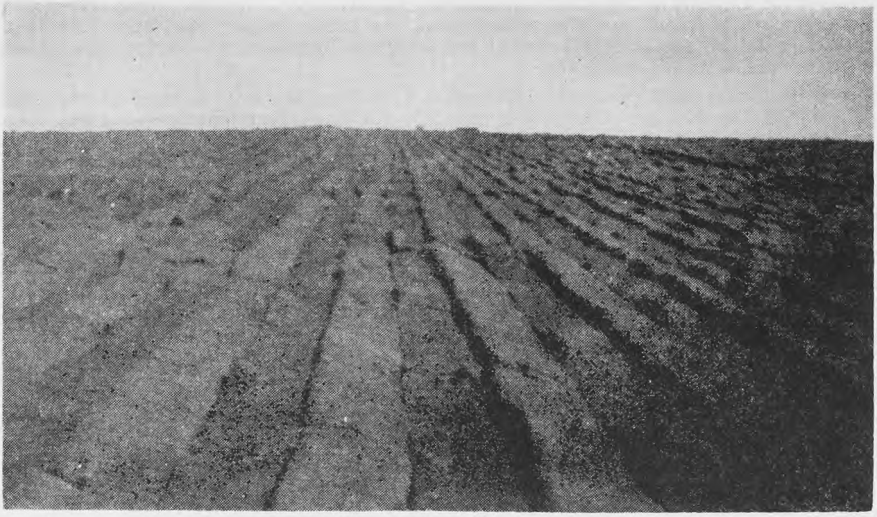

Figure 6.—The Sod after Grasses Contains Fiber for the Soil.

THE EFFECT OF MANURE UPON CROP YIELDS

Six tons of barnyard manure were applied once in six years to plots of several crops which have been sown continuously on the same land. The yields obtained, with and without manure, are shown in Table 8. As an average, all crop yields were increased by manuring, although there were some seasons when there was no increase in the wheat crop. Barley gave an average increase of 4.4, oats, rye and emmer 3.7, flax, 0.7, wheat 0.5 bushels and corn, 0.75 tons of green fodder per acre.

TABLE 8

The effect of manure upon the yields of Wheat, Oats, Barley, Rye, Emmer, Flax and Corn Fodder under Continuous Cropping. Grain yields are in bushels per acre. Corn Fodder yields are in pounds per acre, green weight. R_1 was manured at the rate of six tons per acre once in six years. R_2 was not manured.

Crop	1925-1929	1930-1934	1935-1939	1940-1944	1945-1949	1925-1949
Wheat R_1	27.90	10.07	13.74	18.44	9.82	16.0
Wheat R_2	26.00	10.84	11.34	18.60	10.66	15.5
Oats R_1	57.78	30.36	30.38	40.48	20.16	35.8
Oats R_2	53.88	29.66	28.10	29.06	19.66	32.1
Barley R_1	48.60	25.26	26.74	34.60	18.38	30.7
Barley R_2	41.60	31.50	23.18	27.42	17.58	26.3
Spring Rye R_1	33.86	11.80	15.64	23.04	10.20	18.9
Spring Rye R_2	29.92	10.48	12.92	14.94	7.76	15.2
Emmer R_1	42.70	20.70	14.42	26.32	9.18	22.7
Emmer R_2	35.42	16.26	13.16	23.18	6.84	19.0
Flax R_1	——	7.79	8.36	7.98	5.08	7.3*
Flax R_2	——	7.03	7.58	7.14	4.62	6.6*
Corn R_1	12,394	7,884	8,520	13,806	14,812	11,483
Corn R_2	10,080	7,584	8,144	11,928	12,184	9,984

*Average for 1929-1949 only.

THE YIELD OF WHEAT AS AFFECTED BY CROP SEQUENCE

Yields of wheat in bushels per acre, showing five year and quarter century averages are presented in Table 9. The importance of soil moisture is shown by the fact that wheat, alternating with fallow in Rotation O has yielded about twice as much as an

average for 25 years as the wheat grown continuously in R_2. In other words, about the same amount of wheat, per acre of land used, was grown in each case, but in the first case only half of the land was seeded and harvested, while in the second case, all of the land was sown and harvested.

Introducing sweet clover, as in Rotation T, reduced the average yield of wheat on fallow by 2.5 bushels per acre. This is probably due to the fact that fallowing was done only once in three years instead of every second year. The average yield of wheat following corn was better than that following oats in double rows in each of these rotations. Soil texture has been improved by the sweet clover and this may influence yields more in later years, after the land has been used longer.

In the six year rotation N, fallow, grain, oats in rows, wheat, and hay for two years, which is divided into three parts to compare the effects of alfalfa, brome and slender wheat grass upon the yields of the other crops in the rotation, wheat yielded best after slender wheat grass, and second best after brome grass. It will be remembered that in spite of this higher yield of wheat in the slender wheat grass rotation, the sequence with alfalfa produced the highest average value per acre, as a whole, as shown in Table 2. The best solution of this problem, on a farm, may well be to sow grass and alfalfa together on the same field. Thus, the land will be benefitted by the fibrous roots of the grass and the nitrogen gathering and deep rooting of the alfalfa.

TABLE 9

Effect of Rotation of Crops upon the yield of Wheat in bushels per acre, in comparison with Continuous Cropping.

Name of Rotation	Sequence of Crops	1925-1929	1930-1934	1935-1939	1940-1944	1945-1949	1925-1949
R_1	Wheat, continuously. Manured once every six years	27.90	10.07	13.74	18.44	9.82	16.0
R_2	Wheat continuously. No manure applied	26.00	10.84	11.34	18.60	10.66	15.5
O_1	Fallow, wheat	38.52	30.62	23.14	37.44	27.32	31.4
O_2	Corn, wheat	36.84	18.28	18.60	28.76	13.30	23.2
O_3	Oats in rows, wheat	32.50	14.34	17.14	22.72	13.42	20.0
T_1	Fallow, wheat, sweet clover	37.20	26.12	18.64	36.12	26.54	28.9
T_2	Corn, wheat, sweet clover	36.94	17.58	18.28	33.44	14.84	24.2
T_3	Oats in rows, wheat, sweet clover	34.76	10.82	14.88	25.08	11.98	19.5
N_1	Fallow, grains, oats in rows, wheat, alfalfa, alfalfa	32.20	14.00	15.58	25.30	14.22	20.3
N_2	Fallow, grains, oats in rows, wheat, brome grass, brome	35.62	12.24	17.02	26.14	14.76	21.2
N_3	Fallow, grains, oats in rows, wheat, slender wheat, slender wheat	39.66	12.54	19.10	28.24	15.48	23.0
A	Fallow, wheat, corn, oats, sweet clover	40.36	23.98	22.50	39.08	28.00	30.8
I	Fallow, wheat, oats, alfalfa 5 years	43.52	28.30	24.06	37.40	30.72	32.8
S	Fallow, wheat, oats	37.36	20.26	20.60	36.42	25.60	28.0

In Rotation A; fallow, wheat, corn, oats and sweet clover, wheat has yielded almost twice as much as when grown continuously and 1.9 bushels more than the wheat in Rotation T indicating again that this is an excellent rotation for a farm that can utilize the feed produced. It shows us a practical way to introduce sweet clover into the farming system and thus benefit by its soil improving root system.

In Rotation I, fallow, wheat and oats, supplemented by alfalfa for five years on a fourth field, we find that wheat has given the highest average yield produced in any rotation, 32.8 bushels per acre. This is also one of the two best paying rotations, as a whole. The gain in average yield as compared to Rotation S, fallow, wheat and oats without the alfalfa has been 4.8 bushels per acre.

THE EFFECT OF CROP SEQUENCE UPON THE YIELD OF OATS

Oats were grown in all of the rotations and as continuous crops with and without manure. Average yields in bushels per acre for five and 25 year periods are given in Table 10. The average gain from the use of manure was 3.7 bushels per acre. In years when rainfall was well distributed, the gains were greater while in dry seasons the gains were smaller, illustrating again, how greatly our crop yields depend upon moisture.

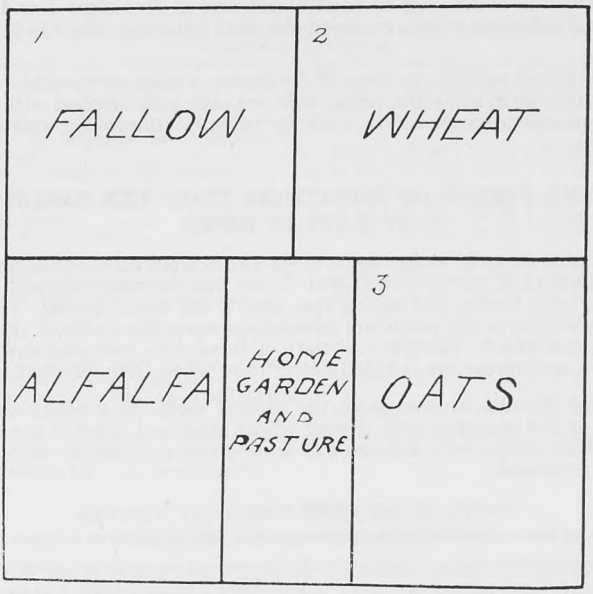

Figure 7.—Rotation I, a Method by Which Alfalfa Was Used as a Supplement.

The average yields of oats from Rotation T exceeded the yields from Rotation O indicating that oats responded better to the improvement in soil condition, due to sweet clover, than wheat did. The average yields following the three different methods of moisture conservation followed the same pattern as the average yields of wheat. That is, they were highest after fallow, second best after corn and third in rank after oats in rows. This gives further evidence that fallow is the best method for moisture conservation with corn second and oats in double rows third. As pointed out before in the comparison of the different rotations, the value of the oats in rows, added to the value of the grain produced following them, has exceeded the value of the grain grown on fallow.

Oats after corn, in Rotation A, averaged 3.4 bushels higher than when following corn in Rotation T. This may have been due to the longer rotation, which permitted the use of two fields for moisture conservation in five years instead of one only in three years. Better weed control and a variation in the methods of moisture conservation in the longer rotation were also important factors.

TABLE 10

Effect of Crop Sequence upon the yield of Oats, in bushels per acre.

Name of Rotation	Sequence of Crops	1925-1929	1930-1934	1935-1939	1940-1944	1945-1949	1925-1949
R_1	Oats continuously. Manured once in six years	57.78	30.36	30.38	40.48	20.16	35.8
R_2	Oats continuously. No manure applied	53.88	29.66	28.10	29.06	19.66	32.1
O_1	Fallow, oats	84.54	61.50	46.94	72.42	52.22	63.7
O_2	Corn, oats	87.18	51.14	45.64	63.60	30.54	55.6
O_3	Oats in rows, oats	67.98	38.72	36.72	47.02	27.32	43.6
T_1	Fallow, oats, sweet clover	94.30	69.78	47.98	80.72	54.40	69.4
T_2	Corn, oats, sweet clover	84.00	48.54	41.38	70.64	34.72	55.9
T_3	Oats in rows, oats, sweet clover	71.54	34.66	35.26	58.00	25.54	45.0
A	Fallow, wheat, corn, oats, sweet clover	86.52	50.72	48.56	66.86	42.12	59.0
I	Fallow, wheat, oats, alfalfa supplement	80.64	31.56	39.10	59.82	38.80	50.0
S	Fallow, wheat, oats	73.80	27.16	41.70	50.72	27.40	44.2

Special attention is directed to results obtained in Rotations I and S, where the yield of oats in I following wheat, exceeded the yield following wheat in S by an average 5.8 bushels.

This is additional evidence in favor of developing a more permanent type of farming even at this early stage, while the better soils are still well supplied with plant food as it shows that substantial gains can be made by using soil improving legumes in a simple type of rotation.

THE EFFECT OF ROTATIONS UPON THE YIELDS OF OATS IN ROWS

Oats in double rows, 36 inches apart or 42 inches from centre to centre were grown in three rotations, O, T, and N. In O and T, the oats in rows followed four different cereals, wheat, oats, barley and spring rye, during the entire period. This enables us to compare the effects of the preceding cereal crops upon the yields of the oats in rows. The data are presented in Table 11. A study of these data indicates that oats in rows, following wheat and spring rye, yielded better than when they followed barley or oats.

In Rotation N, oats in rows gave the highest yields in the sequence containing alfalfa, second in the sequence with slender wheat grass and third in the sequence with brome grass. This agrees with the rank of these three methods in respect to average value per acre produced.

TABLE 11

The effect of Rotation of Crops upon the yield of oats in Rows in bushels per acre.

Name of Rotation	Sequence of Crops	1925-1929	1930-1934	1935-1939	1940-1944	1945-1949	1925-1949
O_3	Barley, oats in rows	57.66	29.66	24.50	43.86	17.24	34.6
	Oats, oats in rows	55.48	32.62	23.50	43.06	16.82	34.3
	Wheat, oats in rows	59.70	37.92	26.80	47.04	17.48	37.8
	Spring rye, oats in rows	61.40	36.46	25.42	47.18	20.36	38.2
T_3	Barley, sweet clover, oats in rows	60.46	36.50	30.18	52.14	22.60	40.4
	Oats, sweet clover, oats in rows	60.60	36.98	28.56	51.26	22.22	39.9
	Wheat, sweet clover, oats in rows	57.80	37.12	29.54	57.08	23.63	41.0
	Spring rye, sweet clover, oats in rows	62.82	34.00	31.86	56.70	24.30	41.9
N_1	Fallow, grains, oats in rows, wheat, alfalfa, alfalfa	66.46	30.14	32.02	54.34	23.14	41.2
N_2	Fallow, grains, oats in rows, wheat, brome grass, brome grass	64.30	26.32	29.38	52.84	20.44	38.7
N_3	Fallow, grains, oats in rows, wheat, slender wheat, slender wheat	68.04	28.18	29.60	53.60	20.20	39.9

REACTION OF BARLEY TO CROP SEQUENCE

Barley was grown continuously, with and without manure and in three rotations, O, T, and N. The average yields in bushels per acre for five year periods and for the entire 25 years are given in Table 12. The response to manuring was excellent, amounting to a gain of 4.4 bushels in the average yield per acre or 110 bushels for the 25 year period.

The yields on the three different methods of moisture conservation in rotations O and T were highest on fallow, second on corn ground and lowest on oats in rows. In rotation N the best yields were obtained from the sequence in which slender wheat grass was used for the hay crop while the sequences containing brome grass and alfalfa ranked second and third respectively. As the barley was grown on summerfallow following two years of these hay crops, it is probable that the higher yields of barley were due to the fact that the roots of slender wheat grass decay quickly leaving the soil in somewhat better tilth a short time after the hay crop had been plowed than it was after brome or alfalfa. Further evidence, supporting this explanation may be found in the fact that oats in rows, two years after the hay crops gave best yields after the alfalfa, the roots having had more time to decay. In practice, it will be very good management to sow slender wheat grass in rotations where the hay crop is wanted for only two or three years and to use alfalfa and brome grass on fields that can be left in meadow for longer periods.

TABLE 12

Effect of Rotation of Crops upon the yield of Barley in bushels per acre in comparison with Continuous Cropping.

Name of Rotation	Sequence of Crops	1925-1929	1930-1934	1935-1939	1940-1944	1945-1949	1925-1949
R_1	Barley continuously. Manured once in six years	48.60	25.26	26.74	34.60	18.38	30.7
R_2	Barley continuously. No manure	41.60	21.50	23.18	27.42	17.58	26.3
O_1	Fallow, barley	65.26	54.22	36.32	52.54	41.94	50.1
O_2	Corn, barley	65.60	41.82	33.56	48.08	27.00	43.2
O_3	Oats in rows, barley	53.04	30.96	27.38	41.56	21.80	34.9
T_1	Fallow, barley, sweet clover	59.48	58.28	35.76	56.08	42.86	50.7
	Corn, barley, sweet clover	56.24	39.42	30.98	48.92	26.38	40.4
	Oats in rows, barley, sweet clover	48.94	29.18	26.34	36.42	23.26	32.8
N_1	Fallow, barley, oats in rows, wheat, alfalfa, alfalfa	59.14	36.02	28.58	49.44	31.22*	40.87
N_2	Fallow, barley, oats in rows, wheat, brome grass, brome grass	59.60	38.50	32.68	48.00	32.80*	42.32
N_3	Fallow, barley, oats in rows, wheat, slender wheat, slender wheat	62.84	45.38	34.26	55.40	36.60*	46.90

*In 1945 and 1946 flax was grown instead of barley in Rotation N. The yield of barley for these years was computed by taking 2.5 times the flax yield.

EFFECT OF CROP SEQUENCE UPON THE YIELDS OF SPRING RYE

Spring rye is not as important a crop as the other cereals in Saskatchewan but it has been grown throughout the 25 year period as a continuous crop with and without manuring and has also been included in rotations O and T. The average yields in bushels per acre are presented in Table 13.

The use of manure, at the rate of six tons per acre once in six years, increased the average yield under continuous cropping by 3.7 bushels per acre or a total of 92.5 bushels for the 25 years. The yields of spring rye, following fallow, corn and oats in rows were very similar to those obtained from wheat, being best after fallow, second best after corn and ranking third after oats in rows.

CORN AS AFFECTED BY CROP SEQUENCE

In these experiments, corn was grown as a fodder crop as this is the safest way to utilize this crop in central Saskatchewan. One or two extra early maturing varieties can usually be depended upon to mature ears in our short seasons but these have short

Figure 8.—Row Crop Stubble Helps to Prevent Soil Drifting.

stalks and do not make a high yield of fodder. Such varieties as Rutherford, a many colored flint corn, can be grown, if desired and used as hog pastures in late summer and fall but the yield of ripe ears has not been sufficient to compete with barley or oats as a grain crop. For that reason, we have used tall growing varieties of dent corn and have harvested the crop with a binder and recorded the green weights. Thus, the yields would be comparable to the yields of silage that could be produced on a farm.

TABLE 13

The effect of Crop Sequence upon the yield of Spring Rye in bushels per acre.

Name of Rotation	Sequence of Crops	1925-1929	1930-1934	1935-1939	1940-1944	1945-1949	1925-1949
R_1	Spring rye continuously. Manured once in six years	33.86	11.80	15.64	23.04	10.2	18.9
R_2	Spring rye continuously. No manure	29.92	10.48	12.92	14.94	7.76	15.2
O_1	Fallow, spring rye	47.18	28.42	28.84	35.80	27.36	33.5
O_2	Corn, spring rye	44.92	19.16	23.80	32.08	14.16	26.8
O_3	Oats in rows, spring rye	36.86	16.52	17.88	25.78	15.42	22.5
T_1	Fallow, spring rye, sweet clover	45.52	26.58	26.28	39.06	28.64	33.2
T_2	Corn, spring rye, sweet clover	43.20	15.72	23.00	36.50	16.92	27.1
T_3	Oats in rows, spring rye, sweet clover	45.20	13.08	18.70	29.24	15.70	24.4

In contrast to the results obtained with wheat, oats, barley and rye, the highest yields were obtained by growing corn on the same land continuously, manured at the rate of six tons per acre, every sixth year, equivalent to one ton per acre per year. This was due to the fact that the thorough cultivation required by corn made it possible to control weeds and conserve moisture each year instead of once in two or three years, as in the rotations. Three quarters of a ton per acre was the average increased yield obtained from the manured land as compared to that which was not manured.

Continuous growing of corn, however, may lead to erosion troubles on account of the cultivation year after year. For that reason, it is gratifying to point to the yields as set forth in Table 14, in which it will be observed that corn yielded almost as much in the long rotation A, as it did when grown continuously. It was also notable that the average yields were better after wheat and oats than when the corn followed barley in rotations O and T.

TABLE 14

Effect of Crop Sequence upon the yield of Corn Fodder in pounds per acre, green weight.

Name of Rotation	Sequence of Crops	1925-1929	1930-1934	1935-1939	1940-1944	1945-1949	1925-1949
R_1	Corn continuously. Manured once in six years	12,394	7,884	8,520	13,806	14,812	11,483
R_2	Corn continuously. No manure	10,080	7,584	8,144	11,928	12,184	9,984
O_2	Corn, barley	11,906	6,906	7,464	11,360	12,120	9,951
	Corn, oats	12,624	7,592	7,930	12,084	12,538	10,554
	Corn, wheat	11,722	7,128	7,784	11,772	13,038	10,289
	Corn, spring rye	10,236	7,292	6,576	10,860	11,536	9,300
T_2	Corn, barley, sweet clover	8,538	6,544	7,506	11,168	13,181	9,387
	Corn, oats, sweet clover	9,478	6,980	7,338	12,102	13,634	9,906
	Corn, wheat, sweet clover	9,616	7,216	7,262	12,704	13,823	10,124
	Corn, spring rye, sweet clover	9,368	7,100	7,796	12,336	14,746	10,269
A	Wheat, corn, oats, sweet clover, fallow	11,607	6,832	8,831	12,894	16,435	11,300

ALFALFA IN TWO ROTATIONS

Alfalfa has been grown in rotation N, as a triennial, being sown each year with wheat on land that produced oats in rows, the previous year and left to produce hay for two years on separate fields. In rotation I, alfalfa was sown with oats and left to produce hay for five years.

This permits a comparison of average yields of hay per acre for fields where alfalfa is grown for different periods. The results are presented in Table 15. It should be observed that the average yield for the second year's crop in rotation N exceeded the yield for the first year by 304 pounds per acre and that the average yield for the field in rotation I, which produces hay for five years was 533 pounds per acre higher. This is further evidence that alfalfa improves after the first year and that it can be used to better advantage as a supplementary crop in a rotation similar to rotation I, than as a crop to be plowed up frequently, as in rotation N.

TABLE 15

Effect of Rotation of Crops upon the yield of Alfalfa in Rotations N and I. Yields are in pounds of hay per acre.

Name of Rotation	Sequence of Crops	1925-1929	1930-1934	1935-1939	1940-1944	1945-1949	1925-1949
	First year after nurse crop—						
N_1	Fallow, grains, oats in rows, wheat *alfalfa*, alfalfa	3,350	544	1,469	2,075	823	1,652
	Second year after nurse crop—						
N_1	Fallow, grains, oats in rows, wheat, alfalfa, *alfalfa*	2,882	1,532	1,384	2,692	1,289	1,956
I	Fallow, wheat, oats, alfalfa supplement	2,967	1,555	1,923	2,302	2,179	2,185

COMPARSION OF YIELDS OF BROME AND SLENDER WHEAT GRASS

Brome and slender wheat grass have been sown with wheat each year in rotation N and left for two years, so that one field represents the first year after seeding and the other field, the second year. The average yields of hay are given for brome grass in Table 16 and for slender wheat grass in Table 17. In each case, the yield of grass improved greatly the second year. This is additional evidence that in farm practice, these grasses can be used as separate meadows or pastures, supplemental to the rotation of annuals, as in rotation I, to better advantage than in systematic sequences, where frequent plowing is required.

TABLE 16

Yields of Brome Grass in Rotation N in pounds of Hay per acre.

Name of Rotation	Sequence of Crops	1925-1929	1930-1934	1935-1939	1940-1944	1945-1949	1925-1949
	First year after nurse crop—						
N_2	Fallow, grains, oats in rows, wheat, brome, brome	2,050	399	1,208	1,260	431	1,070
	Second year after nurse crop—						
N_2	Fallow, grains, oats in rows, wheat, brome, brome	2,784	803	1,263	2,177	1,305	1,666

TABLE 17

Yields of Slender Wheat Grass in Rotation N in pounds of Hay per acre.

Name of Rotation	Sequence of Crops	1925-1929	1930-1934	1935-1939	1940-1944	1945-1949	1925-1949
	First year after nurse crop—						
N_3	Fallow, grains, oats in rows, wheat, slender wheat, slender wheat	2,342	770	793	1,386	584	1,175
	Second year after nurse crop—						
N_3	Fallow, grains, oats in rows, wheat, slender wheat, slender wheat	2,997	1,379	1,224	2,366	1,229	1,839

SWEET CLOVER AS INFLUENCED BY CROP ROTATION

Sweet clover has been grown as a biennial hay crop in two rotations, A and T. The average yields of hay obtained are presented in Table 18. In rotation T, the sweet clover was sown on separate plots with wheat, oats, barley and spring rye on three different methods of moisture conservation, fallow, corn and oats in rows. The clover was harvested for hay in the third year of the rotation.

The average yields indicate that there was not much residual effect of the fallow, corn and oats in rows in the second year upon the clover crop. The clover yields were better after wheat, oats and spring rye than they were after barley. It proved to be easier to secure a good stand of clover with the other cereals as nurse crops than was possible when barley was thus used.

In rotation A, sweet clover was sown with oats on corn ground. The average yield of hay was only slightly lower than that obtained from the same preparation in rotation T.

TABLE 18

Effect of Rotation of Crops upon the yield of Sweet Clover in Rotation T and A in pounds of Hay per acre.

Name of Rotation	Sequence of Crops	1925-1929	1930-1934	1935-1939	1940-1944	1945-1949*	1925-1949*
T_1	Fallow, barley, sweet clover	2,207	1,707	2,554	2,027	2,867	2,272
	Fallow, oats, sweet clover	2,162	2,345	4,323	2,564	2,957	2,870
	Fallow, wheat, sweet clover	3,578	2,376	3,766	2,323	2,481	2,905
	Fallow, spring rye, sweet clover	2,888	2,246	3,014	2,131	2,180	2,492
T_2	Corn, barley, sweet clover	2,889	1,526	2,450	1,897	2,465	2,245
	Corn, oats, sweet clover	2,811	2,038	3,619	2,224	2,652	2,669
	Corn, wheat, sweet clover	3,685	2,306	3,644	2,307	2,618	2,912
	Corn, spring rye, sweet clover	3,254	2,307	3,122	2,048	2,180	2,582
T_3	Oats in rows, barley, sweet clover	3,575	1,444	1,737	1,664	2,286	2,141
	Oats in rows, oats, sweet clover	3,739	2,080	3,182	2,102	2,480	2,719
	Oats in rows, wheat, sweet clover	3,460	2,004	2,829	2,038	2,186	2,503
	Oats in rows, spring rye, sweet clover	3,393	2,029	2,513	1,816	2,589	2,468
A	Fallow, wheat, corn, oats, sweet clover	5,083	2,779	4,117	2,841	2,915	2,547

*In Rotation T, the 1945 and 1948 Sweet Clover crops were destroyed by weevils. These years are excluded from the averages shown.

SUMMARY AND CONCLUSIONS

1. Crop rotation is desirable because many insect pests and plant diseases attack only one crop. By changing the crop, such pests in the soil or stubble are avoided.

2. Rotation helps to conserve the soil. The roots of perennial grasses add fibre and the grass itself covers and protects the land, thus preventing soil drifting and water erosion. The roots of alfalfa and sweet clover are of the branching tap root type which penetrate deeply into the subsoil. When such roots decay, they leave the soil porous so that moisture can be more readily absorbed into the subsoil. These crops also co-operate with bacteria which live in nodules on their roots and these bacteria combine the nitrogen and oxygen from the air into nitrates which are essential plant foods.

3. Rotation makes it possible to control weeds by economical methods. Good stands of grass or mixtures of grass and alfalfa help to choke out many weeds and others are prevented from going to seed by the early harvesting of grass for hay or by grazing. Fallowing and growing crops in clean cultivated rows gives an opportunity to kill weeds at frequent intervals.

4. The benefits of rotation can be obtained without following a completely systematic plan. Alfalfa and grasses may be left on the land as long as they are producing well. Meanwhile, the remaining fields can be rotated with fallow or row crops. A new field of grass or alfalfa should be sown in another location before the old field is plowed. The old field can then be plowed and fallowed in preparation for any grain crop desired. This method of rotating crops is exemplified in rotation I, which has also proved to be a high income producer.

5. Fallowing is the most convenient and efficient method of conserving moisture in this region and should be included in rotations frequently enough to provide for effective weed control.

6. Row crops, such as corn, potatoes and oats in double rows, if kept cleanly cultivated, have considerable value in themselves and also enable one to conserve sufficient moisture to produce a fair grain crop the following year. Of the row crops tried, corn in hills was better than oats in double rows from the standpoint of yield of grain produced the following year but the acreage of corn that can be grown must be limited to the amount required to feed cattle on the farm. Oats in rows can be harvested and marketed as a grain crop or can be harvested early for sheaf feed, if needed. This enables one to raise as large an acreage of oats in rows as he is capable of cultivating properly.

7. Rotation A illustrates a method by which both fallow and a row crop as well as sweet clover, can be introduced into a rotation with five fields. This has also been a high value producer. The rotation can be modified in various ways to suit local needs. The important thing to keep in mind is to have as frequent moisture conservation, as the rainfall record of the district demands.

8. Rotation O, in the experiments, has given very good comparisons of the various cereals when grown after fallow, corn and oats in rows. The grain crop yields were best after fallow but the highest values per acre were obtained by adding the value of the oats grown in rows to the value of the grain crops that followed them. This rotation has no alfalfa or sweet clover in it and requires careful conservation of stubble or manure to keep the soil supplied with humus. Rotation O can be modified easily by using four fields, fallow, wheat, oats in rows and any grain crop desired. This combines the advantages of fallow and row crop on the same farm.

9. Rotation S, fallow, wheat, oats, illustrates the remarkable durability of the soil upon which these experiments were conducted. Rotation S provides for moisture conservation and avoidance of pests that attack only one crop. Conserving stubble and using any manure available will help to maintain the humus content of the soil. This rotation has the advantage of simplicity and the values produced have been fairly satisfactory during the past 25 years. Comparison with rotation I shows that the soil and resulting crop yields were improved by the supplemental field of alfalfa.

10. Rotation N has served a useful purpose in the experiments by giving a comparison of the effects produced by alfalfa, brome grass and slender wheat grass when used as triennials in a systematic rotation. Alfalfa proved best of the three, when considering the rotation as a whole. Slender wheat grass proved to be better than brome, when used as a triennial. However, the use of these perennials as triennials did not prove very satisfactory owing to the cost of seeding every year and the difficulty of securing stands in dry seasons. In general, perennials can be used to better advantage in this climate as supplementary fields, as illustrated by rotation I.

11. Seven crops, wheat, oats, barley, spring rye, flax and corn designated as R_1 and R_2 were grown continuously, with and without manure. As an average, each crop responded to the use of manure by giving an increased yield. While the average values per acre produced by continuous cropping have been fairly good, the risks of crop failure in dry seasons, the difficulty of controlling weeds and other pests, and the cost of seeding the entire acreage each year have all indicated that continuous growing of the same grain crop is inferior to crop rotation as a method of farming in this region but corn fodder gave good yields as a continuous crop and responded well to manuring.

12. Protein content of wheat produced in the various sequences did not vary a great deal. This may have been due to the fact that the wheat was usually sown on fallow or cultivated land in the different rotations and sufficient nitrates were available to supply the protein developed. Seasonal observations confirmed the belief that in years when bright, dry weather hastens the ripening of the wheat, the percentage of protein is higher than when the ripening period is prolonged by cool or wet weather.

13. No important differences in the size of kernels were found in barley and oats when grown in different sequences but the kernels of wheat and spring rye were larger when grown on cultivated fallow or corn ground than when grown as continuous crops.

14. These experiments have given valuable data in regard to many farming problems under conditions of limited rainfall. They should be continued in order to establish basic facts about dry land agriculture in much the same manner as the classical experiments at Rothamstead, England, have been continued under humid, climatic conditions. Modifications can be made as indicated by time and further experience.

ACKNOWLEDGMENTS

Conducting these experiments over a quarter of a century has involved the help of a number of members of the staff of the Field Husbandry Department, both past and present.

Former staff members who collaborated in this work included Roy Hanson, Trueman Stevenson, Thomas Townley-Smith, Arthur Marshall, William Gilmer, Alice Wall, Hazel Holm, and Elva Hewitt.

Present members of the staff who have assisted materially with these projects include Howard Gerrie, Orest Mysak, Edith Robinson and Charles Anweiler. Their help is gratefully acknowledged.

Appreciation is also expressed to the Chemistry Department for making the protein determinations for the wheat grown in these experiments.

Printed April, 1951